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Numerical Modeling and Prediction of Thermomechanical Degradation of Power Electronic Packaging

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ABSTRACT

This work aims at numerical thermomechanical studies of two types of high temperature silver connections elaborated at low temperatures, the transient liquid phase bonding (TLPB) of Ag-In and silver nanoparticles sintering, using test vehicles representing the final packaging assemblies of diamond components. The simulation is performed using a finite element code on 2D and 3D assemblies. The stress distribution in the assemblies and in the two die-attachments was studied during thermal cycling in the range temperature between -50 and 300°C. A comparison of these two technology trends with respect to their applicability for power electronics packaging was conducted.

Introduction

Modern power electronics is facing two major challenges: On the one hand there is the demand for hot environment applications such as electrical or hybrid vehicles [1]. Moreover the current density increase of new chip generations leads to an increase in heat losses [2, 3]. On the other hand new markets like renewable energies call for lifetime increase and high reliabilities [4, 5]. As a result it is a fact that alternative joining technologies are needed for high temperature applications in power electronics. In case of the chip to substrate joint a high thermal and electrical conductivity as well as a good mechanical stability of the die-attach material within the whole operation temperature is needed [5]. In this work, we propose to study the prediction of the thermomechanical degradation behavior of two types of high temperature connections elaborated at low temperatures: Ag-In based connection obtained by diffusion heat treatment and silver nanoparticles obtained by sintering process.

Packaging Architecture and Methodology

To predict the thermomechanical degradation behavior of the test vehicle, a geometrical model of 2D and 3D electronic assemblies are built in the finite elements code Abaqus®. The FEM architecture is presented in the figure 1 [2, 5]. The power electronic packaging is composed of a diamond die, of dimensions 3×3×0.5 mm, and a copper metallized ceramic substrate Si₃N₄ which are bonded together with either TLPB Ag-In or silver nanoparticles sintering. The thickness of the Ag-In and nano Ag joints is about 100 µm. Since the electronic assembly is symmetric, a half model is considered in these computations.

Anand constitutive model is used here to describe the viscoplasticity of the die-attachments materials [6, 7]. The diamond die and Si₃N₄ ceramic substrate are taken as pure elastic materials. Copper metallization is considered to have elastoplastic mechanical behaviour.

The packaging is subjected to thermal cycling as presented in figure 2. The thermal cycle is decomposed into a reflow cycle included in the manufacturing process and a thermal temperature cycling imposed for a temperature range of -50°C to 300°C with a heating/cooling rate of 20°C/min. A dwell time of 30 min is considered at -50°C and 300°C. The imposed heating/cooling profile is

composed of 5 cycles. During the elaboration process and thermal cycling, the mismatch of thermal expansion coefficients (CTE) between the die and the substrate caused stress and viscoplastic strain in the bonding layer [5, 8]. After the simulations and in order to observe the CTE mismatch effects on the thermomechanical behaviour of the junction, the stress and the strain values are extracted on the bonding layer for comparison purposes between the two die attachments.

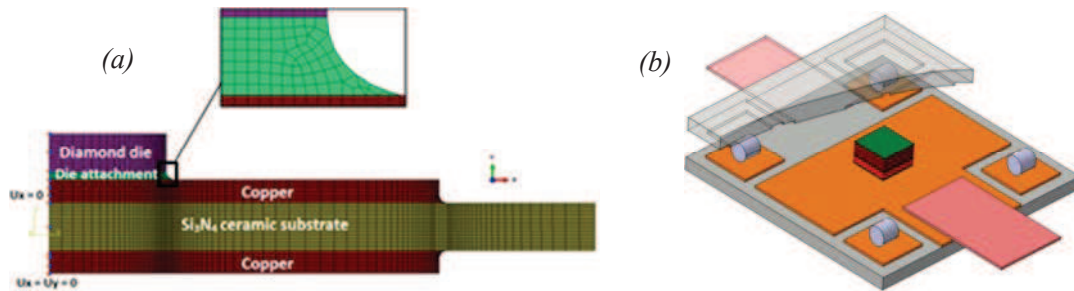


Figure 1. Finite element modeling of the power electronics packaging, (a) 2D packaging architecture, (b) 3D packaging architecture.

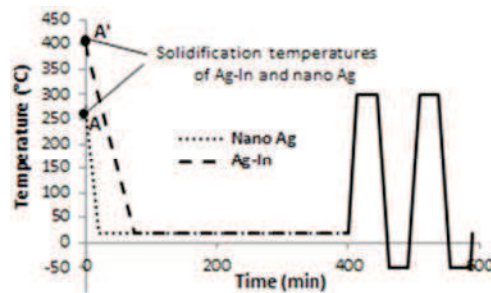


Figure 2. Imposed temperature profile for the Ag-In and nano Ag joints.

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